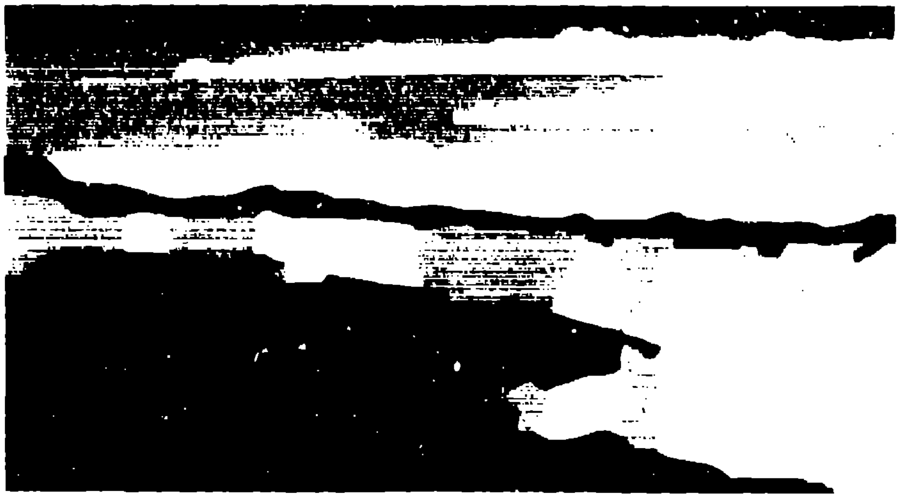
LA-UR-93-1847

Title: THE LOS ALAMOS VXI-BASED MODULAR RF CONTROL SYSTEM

Author(s): S. P. Jachim, C. Ziomek, E. F. Natter, A. H. Regan, J. Hill, L. Eaton, W. D. Gutscher, M. Curtin, P. Denney, E. Hansberry and T. Brooks

Submitted to: 1993 Particle Accelerator Conference
May 16-20, 1993
Washington, DC



Los Alamos
NATIONAL LABORATORY

Form No. 836 R5

The Los Alamos VXI-Based Modular RF Control System*

S. P. Jachim, C. Ziomek, E. F. Natter, A. H. Regan, J. Hill, L. Eaton,
W. D. Gutscher, M. Curtin, P. Denney, E. Hansberry, T. Brooks
MS-H827, Los Alamos National Laboratory, Los Alamos, NM 87545

Abstract

This paper describes the design and implementation of the Los Alamos modular RF control system, which provides high-performance feedback and/or feedforward control of RF accelerator cavities. This is a flexible, modular control system which has been realized in the industry-standard VXI card-modular format. A wide spectrum of system functionality can be accommodated simply by incorporating only those modules and features required for a particular application. The fundamental principles of the design approach are discussed. Details of the VXI implementation are given, including the system architecture and interfaces, performance capabilities, and available features.

Introduction

The AT-5 group at Los Alamos National Laboratory (LANL) is developing the RF system for the Ground Test Accelerator (GTA), including the RF control system, which is the topic of this paper. The GTA Program is a development vehicle for Neutral Particle Beam (NPB) physics and technology.

Because GTA operates at several different harmonically-related frequencies using various power amplifier technologies, a decision was made early on to pursue a modular RF control system architecture. This architecture is designed to be independent of RF frequency, power level, and type of accelerating structure. This approach has proven successful on GTA, and has allowed the same hardware to be used in a wide variety of other accelerator applications worldwide.

The first LANL VXI module for RF control was designed and built in 1987, and the fourth complete control system was operated on GTA in 1992. Additionally, four other systems have been installed and operated at various other institutions. In all, about C-size VXI modules have been built to date.

System Requirements

The primary purpose of an RF control system is to tightly regulate the accelerating and/or focusing field in an accelerator cavity [1]. This regulation must be maintained in the presence of variations in the accelerator system parameters, such as cavity resonant frequency, beam current, and power amplifier performance. The design objective for field regulation tolerance in the GTA RF control system is ±0.5% in amplitude and ±0.5° in phase. This applies for beam loading conditions up to 80%.

*Work supported and funded by the US Department of Defense, Army Strategic Defense Comm and, under the auspices of the US Department of Energy

To achieve this level of regulation and to ensure efficient RF power transfer to the cavity, the resonant frequency of the accelerator cavity must be maintained within prescribed limits. A regulation tolerance of ±2° was chosen as an objective for the cavity reflection coefficient phase on GTA.

System Architecture

Figure 1 illustrates the essential aspects of the LANL RF control system architecture as applied to a particular accelerating cavity [2,3]. A sample of the cavity field is downconverted to a 20MHz IF and synchronously detected against the RF reference signal. The in-phase (I) and quadrature-phase (Q) components of this detected signal are compared to their respective commanded values, or setpoints.

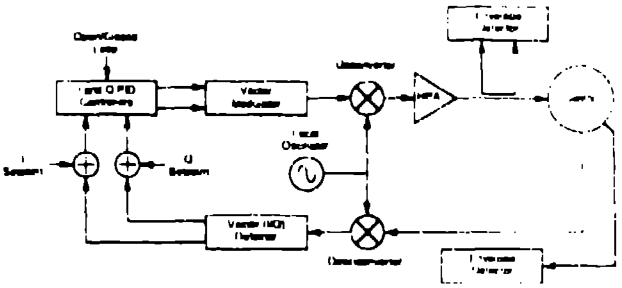


Figure 1. LANL RF control system architecture.

The difference between the detected components and their setpoints produces an error vector. Proportional, integral, and differential (PID) closed-loop control actions are then derived from this error vector, producing a control vector. An open loop control vector can optionally be generated at the beginning of the acceleration cycle to fill the cavity in a programmed manner.

A vector modulator translates the control vector to a 20MHz IF carrier, which is subsequently upconverted back to the original RF frequency. This RF control vector is applied to a high-power amplifier (HPA) whose output is an RF cavity drive vector, closing the feedback loop.

The RF control system is partitioned into several functional VXI modules as shown in figure 2. The modules with solid outlines constitute the basic RF control system. The modules with dashed outlines are optional system components, and can be incorporated as desired to enhance the performance of the basic control system. The Beam Feedforward Module estimates the beam loading disturbance and applies appropriate feedforward signals to minimize field perturbations. The Control Predistorter Module provides dynamic decoupling of the I and Q control rails, which are cross coupled by the cavity. The Adaptive Feedforward Module measures, integrates, and corrects repetitive loop disturbances in a pulsed RF system. Details of these optional modules can be found elsewhere [2-5].

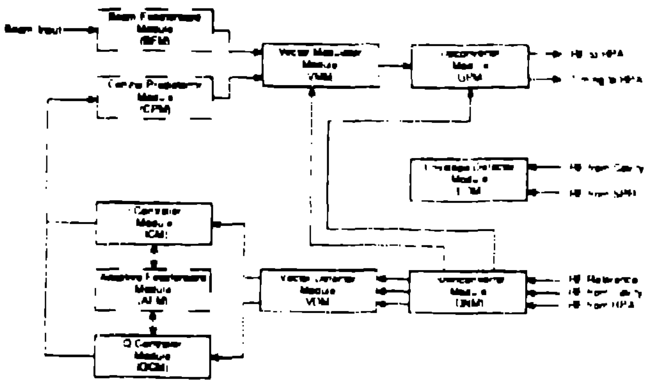


Figure 2. VXI modular implementation.

Feedback control is also employed to regulate the resonant frequency of the cavity [6,7]. As shown in figure 3, this is achieved by detecting the forward- and reverse-traveling waves in the cavity drive line, computing the cavity reflection coefficient, and taking corrective feedback action by applying a control signal to a mechanical cavity tuner. Accuracy is assured by calibration and vector error correction [8]. All computations for this process are performed in software, and the feedback loop is closed through a virtual network connection to the tuner actuator.

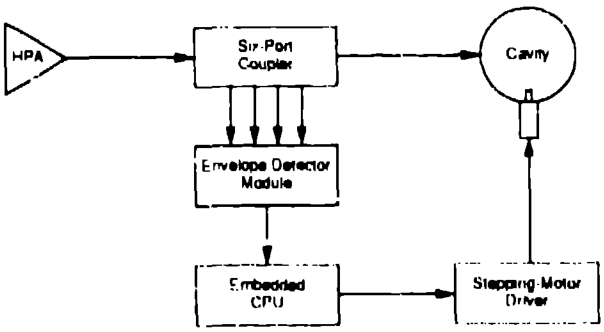


Figure 3. Resonance control system.

Several ancillary functions are assigned to the RF control system as well. Measurements of various RF signal amplitudes in the system, such as the cavity field amplitude and drive, are supported with Envelope Detector Modules. These modules sample and quantize each of eight RF input signals once per RF pulse.

The RF system associated with each cavity is sequenced and timed by the RF control system. This function is performed in the Upconverter Module, which sends two independent optical timing signals to the HPA.

The RF system, like the rest of the accelerator, is required to operate remotely under complete automation. Thus, supervisory computer control, data acquisition, and remote signal monitoring are implemented in the GTA RF control system. All relevant RF control system parameters are writeable and readable through the GTA database, and all control functions are integrated and operated through EPICS control screens.

Hardware Realization

The VME Extensions for Instrumentation (VXI) standard [10] which emerged in the 1988-89 time frame was developed by a consortium of leading instrument manufacturers. This standard builds on, and is compatible with, the ubiquitous and powerful VME standard to produce a robust card-modular medium capable of supporting high-performance analog, digital and microwave instruments. The design of the RF control system commenced in this time period, and VXI was chosen as the packaging medium. VXI held promise of not only supporting the needs of the RF control hardware, but also of fitting seamlessly into the GTA computer control system, it being of a VME-based distributed architecture.

The promise of VXI has held true in practice. Most of the RF control modules have been, of necessity, designed in house. In all cases, strict adherence to the VXI standard has been maintained. Several commercial VME cards, such as a 68020-based processor and an Ethernet interface card, had already been integrated into the computer control system. These VME modules were directly embedded in the VXI RF control system and integrated together without significant difficulty.

Figure 4 shows a conceptual layout of a typical LANL VXI module. Details of the register-based VXI interface can be found elsewhere [9]. All timing and signal conversion functions are distributed down to the module level. A 10MHz clock and a synchronizing trigger are broadcast to all modules on the VXI backplane. Counters on each module's interface circuit count down from preloaded register values and provide on-board timing signals. As needed, A/D and D/A converters are provided in situ on each module. Signal sampling is triggered by the on-board timing signals, which are under software control. This approach greatly simplifies system integration and configuration management. Because the number of connectors and cables in the system has been minimized, reliability is improved.

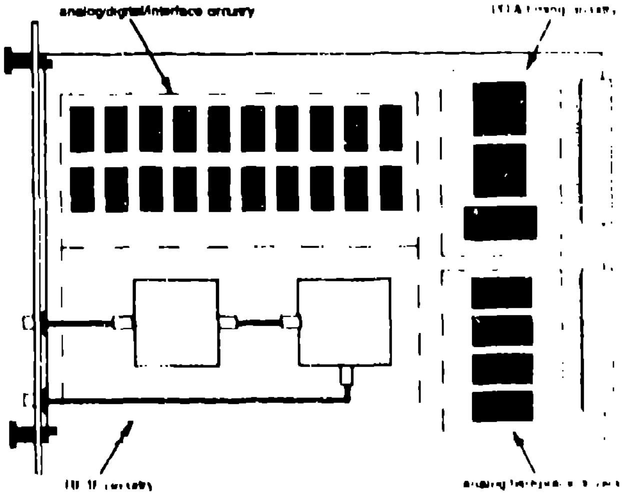
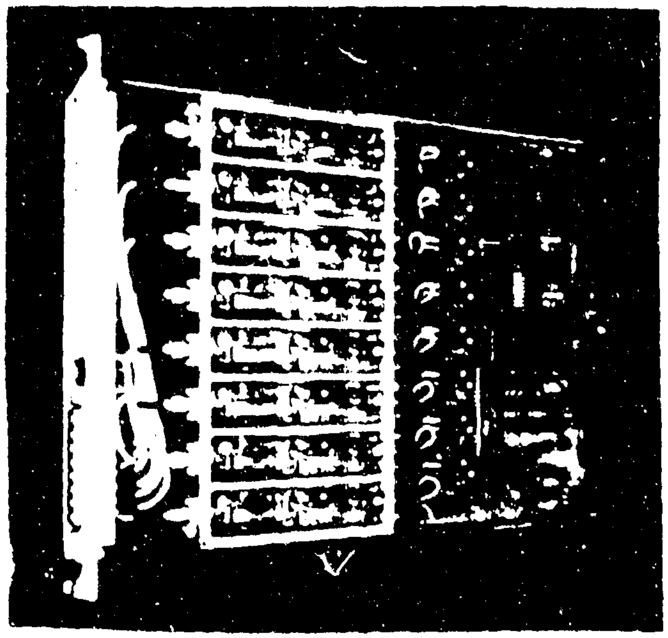


Figure 4. Conceptual VXI module layout.

Analog, digital, and mixed signal circuitry is judiciously combined on the LANL VXI printed circuit (PC) boards. The structure of these PC boards ranges from 2 to 10 layers.



Other Applications

Summary

References